International Symposium on Stochastic Complex Systems Title and Abstracts

Friday, May 22, 2026

9:10 – 9:45: Kevin Pitts,

Title: *Other Complex Systems: Education & Leadership*

Abstract: Prof. Pitts will discuss Michel Pleimling's contributions to Virginia Tech's educational mission, his dedication to student success, and his role as a leader in the College of Science.

9:45-10:20: Malte Henkel - Zoom,

Title: *Schrödinger-invariance in the Voter Model*

Abstract: In the voter model with nearest-neighbor interactions, the exact single-time and two-time correlations and the two-time response function are found for the order-parameter, and their explicit dynamical scaling functions are continuous functions of the space dimension $d>0$. Their form reproduces the predictions of non-equilibrium representations of the Schrödinger algebra for models with dynamical exponent $z = 2$ and with a dominant noise source coming from the heat bath. Hence, aging in the voter model is a paradigm for relaxations in non-equilibrium critical dynamics without detailed balance, with the upper critical dimension $d^* = 2$.

10:50 -11:25: Uwe Täuber,

Title: *Invading Activity Fronts Stabilize Excitable Systems Against Stochastic Extinction*

Abstract: Stochastic chemical reaction or population dynamics in finite systems often terminate in an absorbing state. Yet in large spatially extended systems, the time to reach species extinction (or fixation) becomes exceedingly long. Tuning control parameters may diminish the survival probability, rendering species coexistence susceptible to stochastic extinction events. In inhomogeneous settings, where a vulnerable subsystem is diffusively coupled to an adjacent stable patch, the former is reanimated through continuous influx from the interfaces, provided the absorbing region sustains spreading activity fronts.
We demonstrate this generic elimination of finite-size extinction instabilities via immigration flux in predator-prey, epidemic spreading, and cyclic competition models. This research was (in part) supported by the U.S. National Science Foundation, Division of Mathematical Sciences under Award No. NSF DMS-2128587.

Kenneth A.V. Distefano, Sara Shabani, and Uwe C. Täuber

11:25 -12:00: Priyanka - Zoom,

Title: *Memory of topologically Constrained Disordered in Shakti Artificial Spin Ice*

Abstract: Complex behaviors often sit at a critical threshold between order and disorder. But not all disorders are created equal. Disorders can be trivial or constrained, and correlated disorders can even be topological. Crucially, constrained disorder can harbor memory, leading to non-trivial, sequence-dependent responses to external manipulations. And yet the fascinating subject of "memory of disorder" remains poorly explored, as memory is often associated with the retention of metastable order. In this talk, I will discuss the sequence-dependent responses of two somewhat opposite yet related artificial spin ices: the Landau-ordered square spin ice and the disordered but topologically ordered Shakti spin ice. We find that Shakti exhibits a pronounced sequence-dependent response, whereas in the square lattice, such path dependence is absent. Within Shakti, even the minimal periodic supercell demonstrates both deterministic and stochastic forms of sequence memory, depending on the interaction strength. Extending our study to cyclic driving, we find that retracing the same input path enhances memory retention.

1:30 -2:05: Ulrich Dombramysl - Zoom,

Title: *Why Do Ants Stop in the Middle of Traffic?*

Abstract: I will talk about our work on emerging traffic patterns of Argentine ants as they cross a narrow bridge between their nest and a food source. We discovered that a small subset of ants stays stationary, acting as obstacles and affecting the flow of traffic around them. Furthermore, the fraction of stopped ants increased disproportionately when the ants crossed a wider bridge, suggesting a mechanism that constrains traffic flow to a narrower section of the bridge. We measured the average speed of the ants on the bridge as a function of the windowed ant arrival rate and found it to be monotonically increasing. To better understand these dynamics, we developed an agent-based model for ant movement and interactions. Including stopped agents in the model was crucial to explaining the experimental observations. We further validated our hypothesis by introducing artificial obstacles on the bridges and found that our simulations accurately mirrored the experimental data when these obstacles were included. These findings provide new insights into how Argentine ants self-organize to manage traffic, highlighting a unique form of dynamic obstruction that enhances traffic flow in high-density conditions.

2:05 -2:40: Christian Binek,

Title: *A Random Walk through the Physics of an Archetypal Magnetoelectric Antiferromagnet*

Abstract: I report on a multi-decade, not entirely random walk through the physics of the archetypal magnetoelectric antiferromagnet Cr_2O_3 (chromia)[1] and its boron-doped variants.[2] These systems have, at times, felt like a kind of "philosopher's stone," enabling both fundamental condensed matter studies and spintronic applications. A central result is the possibility of dissipation less, purely voltage-controlled rotation of the Néel vector, enabling ultra-low-power, nonvolatile, and potentially ultrafast antiferromagnetic memory and logic beyond CMOS. B:Cr_2O_3 thus emerges as a strong candidate for pure voltage-controlled antiferromagnetic spintronics operating at zero magnetic field and CMOS-compatible temperatures.[2] I present magneto transport measurements on lithographically fabricated B:Cr_2O_3/Pt Hall-bar devices, including the effects of thermal annealing. The data are interpreted in terms of nonvolatile voltage-controlled $\pi/2$ Néel vector rotation and surface segregation, supported by scanning probe and NV-center microscopy,[3] micro-Raman spectroscopy, cold neutron scattering, and X-ray photoemission depth profiling. I also discussed a recently engineered isotropic magnetoelectric material that provides access to axion electrodynamics, as originally proposed by Frank Wilczek in high-energy physics, establishing a condensed matter platform for this phenomenon.[4] This opens pathways toward magnetoelectric Hall effects, magneto photovoltaic responses, and monopole-based device concepts. Finally, I address proximity effects in chromia-based heterostructures, where voltage-controlled switching can influence spin-dependent transport in adjacent two-dimensional (2D) materials, including graphene and 2D magnets. This has motivated renewed Monte Carlo studies of the 2D anisotropic Heisenberg model. I present our recent results on systematically reducing single-ion anisotropy toward the 2D Heisenberg limit, where long-range order is lost, and connect back to earlier work with Michel Pleimling,5 who performed extensive Monte Carlo simulations on model systems such as $FeCl_2$ and $FeBr_2$, which we studied experimentally.

2:40 -3:15: Ferenc Igloi - Zoom,

Title: *Quench Dynamics of the Quantum XXZ Chain with Staggered Interactions: Exact Results and Simulations on Digital Quantum Computers*

Abstract: We investigate quench dynamics in a quantum \$S=1/2\$ XXZ antiferromagnetic chain with staggered and anisotropic interactions in the flat-band limit. Our quench protocol interchanges the odd- and even-bound strengths of the fully dimerized Chain, enabling us to derive exact time-dependent states for arbitrary even system sizes by working in the Bell basis. We obtain a closed-form, size-independent expression for the von Neumann and second-order R/'enyi entanglement entropies. We further compute exact Loschmidt echoes and the corresponding return-rate functions across various anisotropies and system sizes, and identify Loschmidt zeros in finite chains. Our analysis reveals distinct finite-size scaling of the Loschmidt echo at critical times with chain length and identifies the precise conditions on the anisotropy parameter governing the periodicity of the dynamical observables. In addition to the analytic study, we perform two types of numerical experiments on IBM-Q quantum devices. First, we use the Hadamard test to estimate the Bell-basis expansion coefficients and reconstruct the dynamical states, achieving accurate entanglement entropies and the Loschmidt echo for small systems. Second, we implement Trotter-error-free-time-evolution circuits combined with randomized Pauli measurements. Post-processing via statistical correlations and classical shadows yields reliable estimates of the second-order Rényi entanglement entropy and the Loschmidt echo, showing satisfactory agreement with exact results.

4:30 -5:05 Andres Concha,

Title: *Macroscopic Bioinspired Magnetic Active Matter and the Physical Limits of Magnetotaxis*

Abstract: Magnetostatic bacteria (MTB) are endowed with an exquisite orientation mechanism allowing them to swim along the geomagnetic field lines. This mechanism consists of a chain of bio-synthesized magnetic nanocrystals that endow MTB with a permanent magnetic moment. Although physics behind the minimum size of this biological compass is well understood, it is yet unclear what sets its maximum size. Here, using a macroscopic experiment inspired by these microorganisms, we show that larger magnetic moments' drive the collective behavior of MTB into a phase in which bacteria are unable to swim freely, to the detriment of their evolutionary fitness. Simple macroscopic experiments, numerical simulations, and analytic estimates are used to determine the upper limit on the size of the nanocrystal chain in MTB. Our macroscopic bio-inspired experiment and physical model provide new opportunities to explore and understand the phases of magnetically active matter at all scales.

5:05 -5:40 Shadi Esmaeili-Wellman,

Title: *Post-Treatment Viral Rebound: A Mechanistic Modeling Approach*

Abstract: Viral rebound, defined as the resurgence of viral load after an initial decline under treatment, has been widely observed following antiviral therapy, including SARS-CoV-2. It is often attributed to factors such as viral resistance, persistent reservoirs, or insufficient treatment potency or duration. During the SARS-CoV-2 pandemic, rebound following treatment with Paxlovid, one of the most promising and effective antivirals, raised concerns about its effectiveness and complicated clinical use. In this talk, I use a simple mechanistic model of within-host viral dynamics to examine the mechanisms underlying post-treatment viral rebound. I show that the interplay between antiviral treatment and the developing immune response can generate rebound dynamics without invoking additional mechanisms. In particular, the model predicts that early, potent treatment can suppress viral load while dampening early immune control, increasing the likelihood of resurgence after treatment ends. Our model also provides treatment suggestions to lower or eliminate rebound.

Saturday, May 23, 2026

8:35 -9:10 Andrea Gambassi - Zoom,

Title: *Transport of Bosons and Fermions in 1D: a Unified Picture*

Abstract: In this talk, I explore the dissipative transport of bosons and fermions on a one-dimensional lattice, where particle hopping is mediated by coupling to a Markovian reservoir. In the bosonic case, the resulting dynamics are described by the classical asymmetric inclusion process (ASIP), in contrast to the asymmetric exclusion process (ASEP) governing fermionic transport. Despite this fundamental difference, current fluctuations exhibit strikingly similar behavior at large scales, although their full counting statistics remain distinct. By mapping both dynamics onto fluctuating interface models, we show that they belong to the Kardar–Parisi–Zhang universality class, with bosonic transport corresponding to surface growth and fermionic transport to erosion. This unified framework clarifies both similarities and differences between the two cases, with potential relevance for cold atoms and nanophotonic platforms.

9:10 -9:45 Hildegard Meyer-Ortmanns - Zoom,

Title: *Heteroclinic Dynamics: From Ecological Systems to Brain Dynamics*

Abstract: Based on previous work on (N,r)-games of competition, we discuss our subsequent work on heteroclinic dynamics with possible applications to transient processes in ecological systems and neuronal networks. We construct a hierarchy in attractor space that yields nested spirals when viewed on a regular spatial grid. One focus is on information transfer across the grid when the temporal order of excited subpopulations of neurons encodes the information that is included in external signals. On spatial grids of coupled heteroclinic units, we find critical behavior in the vicinity of bifurcation points and slow relaxation dynamics when we quench the bifurcation parameter to a resting state of the system. We indicate ongoing work on an alternative way of generating switching between metastable states in oscillatory systems that is induced by non-reciprocal adaptive couplings in these models.

9:45 -10:20 Claude Godrèche - Zoom,

Title: *Optimal Navigation Trajectories*

Abstract: What is the optimal strategy for a sailboat sailing upwind to reach a target in minimal time in a wind of varying direction?

10:50 -11:25 Wolfhard Janke - Zoom,

Title: *Coarsening and Aging in the Two-dimensional Ising Model with Algebraic Long-range Interactions*

Abstract: An overview of coarsening and aging in the paradigmatic two-dimensional Ising model with power-law decaying long-range interactions $\sim r-(2+\sigma)$ is given, where σ is a tunable decay parameter. After a brief discussion of our results for phase ordering in the non-conserved case, the presentation will focus on phase-separation kinetics with a conserved order parameter. Using large-scale Metropolis Monte Carlo simulations enabled by our novel algorithm for long-range interacting systems, we investigate deep quenches from $T = \infty$ to a finite temperature well below Tc. First, long-standing theoretical predictions for the dynamic exponent $z = z(\sigma)$ are verified with high numerical precision. Next, physical aging encoded in the power-law decay of the two-time auto-correlation function $C (t, tw) \sim (t/tw)-\lambda/z$ is studied. For the autocorrelation exponent λ, we observe a complex dependence on σ: In the limit $\sigma \to \infty$ (recovering the nearest-neighbor model), a value of $\lambda = 3.500(26)$ is determined. In the truly long-range regime for $0 < \sigma < 1$, the

values of λ are all compatible with λ ≈ 4. In between, for 1 < σ .2, where also the equilibrium critical exponents show a non-trivial σ dependence, a continuous crossover is visible with σ-dependent values of λ.

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11:25 -12:00 Nasrin Afzal

Title: *Mechanistic Insights into Corticosteroid Modulation of Immune Response and Cytokine Release Following Subcutaneous Epcoritamab using QSP Modeling*

Abstract: Epcoritamab is a CD3×CD20 bispecific antibody that induces T-cell–mediated cytotoxicity in CD20+ B cells. Cytokine release syndrome (CRS) is a key safety concern for T-cell engagers and is mitigated clinically using step-up dosing (SUD) and prophylactic corticosteroids. SUD regimens have been investigated and optimized to minimize the risk of CRS in EPCORE NHL-1 (NCT03625037). This study aimed to evaluate the impact of corticosteroids (e.g., dexamethasone, prednisolone) on immune response and cytokine release using a QSP model. Methods: An integrated QSP framework combining a minimal PBPK/PD model of Epcoritamab with a corticosteroid model was developed using preclinical and clinical data. The model captures T-cell activation, proliferation, cytotoxicity, and cytokine dynamics across blood, lymphoid, and tumor compartments. Simulations were conducted in a calibrated virtual patient population to assess the effects of corticosteroid regimens on pharmacodynamic biomarkers and clinical responses.
Results & Conclusions: Simulations showed transient, modest cytokine elevations following subcutaneous Epcoritamab administration. Corticosteroids modulated immune cell activity and reduced cytokine release, with biomarkers such as IL-6 and IL-10 reflecting these effects. The QSP model provides mechanistic insight into how prophylactic corticosteroids mitigate CRS while preserving therapeutic activity in B-cell NHL patients.

1:30 -2:05 Mauro Mobilia - Zoom,

Title: *Fixation and Extinction in Time-fluctuating Metapopulations*

Abstract: Bacterial populations often evolve in spatially structured, time-varying environments shaped by migration and local fluctuations. In this talk, we consider metapopulation models where wild-type and mutant cells compete on graphs of demes (subpopulations) connected by slow migration. Each deme has the same carrying capacity that endlessly switches between two values representing harsh and mild environmental

conditions. When the switching rate is neither too slow nor too fast (intermediate switching), demes experience recurrent bottlenecks, leading to strong fluctuations and possible extinction. We show how migration, space, and environmental fluctuations shape fixation and extinction across different graph topologies (cliques, cycles, and square lattices). When bottlenecks are weak (no deme extinction), fixation depends on migration and can vary non-monotonically with the switching rate, which can be explained by a coarse-grained description. Under strong bottlenecks, evolution is driven by the interplay between deme extinction and strain competition, leading to rich dynamical scenarios. We identify conditions that maximize mutant eradication while preventing total population collapse and offer an interpretation in terms of an idealized treatment strategy. This is a joint work with Matthew Asker, Mohamed Swailem, and Uwe C. Täuber, supported by the EPSRC and NSF. Project website: https://eedfp.com/
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2:05 -2:40 Jason Czak,

Title: *Creating Novel Patterns with Localized Perturbations in Non-linear Reaction-Diffusion Systems*

Abstract: The Gray–Scott reaction–diffusion model is renowned for its ability to generate a wide range of spatiotemporal patterns observed in natural systems. These include stationary pulses, traveling waves, self-replicating structures, coarsening dynamics, and transient chaos. While the model has been extensively studied, modifications incorporating electric fields, time-delayed feedback control (TDFC), and intrinsic parameter variations continue to reveal new dynamical behaviors. In this study, we design and implement targeted protocols that apply electric field effects, parameter variations, and TDFC to spatially localized regions of the system to generate novel patterns. By strategically manipulating established parameter-space regimes, we scale localized perturbations to produce emergent

structures and gain deeper insight into the connections between distinct dynamical behaviors.

2:40-3:15 Royce Zia - Zoom,

Title: *Surprises in Nonequilibrium Steady States*

Abstract: In my explorations of steady states in systems driven far from equilibrium, surprises continue to surface – not only in complex systems, but also in some pedantically simple ones. After a brief introduction on the significance of stochastic systems evolving without detailed balance and the emergence of persistent probability currents in stationary states, I will illustrate with an example or two. The simplest involves a biased random walker in 1D, for which few might imagine puzzles can exist! Time permitting, I will briefly show a different type of surprise, discovered recently in simulations of a more complex system – a coarse-grained version of the driven Widom-Rowlinson lattice gas [PRE 113, 014105].

3:45-4:20 Ben Intoy,

Title: *Effects of Diffusion and Temperature on a Model of Prebiotic Evolution*

Abstract: I will summarize the research I conducted at the University of Minnesota (UMN) as a postdoctoral fellow under Professor J. Woods Halley after graduating from Virginia Tech. My primary focus was expanding upon a Kauffman-like model of prebiotic evolution. The initial model assumed a well-mixed system at infinite temperature with measures and cutoffs on entropy and dynamics to determine lifelike steady states. The first expansion was to add space to the model, allowing polymers to hop and diffuse to/from neighboring sites. The second expansion allowed for finite temperatures and accounted for bond energy, which affected reaction rates. In both cases, it was discovered that the system can be far from or close to different equilibrium criteria. At the end of my presentation, I will also have an abbreviated summary of the work I currently do at Deloitte Consulting LLP.

4:20-4:55 Nadir Kaplan,

Title: *Geometric Theory of Elastic Curves Bounded on Non-Euclidean Surfaces*

Abstract: I will present a first-principles geometric theory of extensible elastic filaments constrained on non-Euclidean surfaces. In addition to bend and twist, typical in existing phenomenological theories, our constitutive model leads to an Almansi strain-measure term for stretching as an intuitive description of extensible filaments. Our solution to this

problem paves the way for understanding anisotropic filament shapes, as well as thermal and biochemical kinetics on biological surfaces, ranging from DNA wrapping around histones to contractile actin rings at the cell membrane during cytokinesis.

4:55-5:30 Shengfeng Cheng,

Title: *Colloidal Diffusiophoresis*

Abstract: Diffusiophoresis is the spontaneous motion of particles driven by a concentration gradient of another substance. Traditionally, this "other substance" is a salt composed of ions much smaller than the phoretic particles themselves. In this talk, we investigate a new regime of colloidal diffusiophoresis, where the gradient is generated by solute particles of a size comparable to, or even larger than, the phoretic particles. This mechanism has recently been identified as the driver behind stratification in rapidly drying polydisperse suspensions. Using large-scale molecular dynamics simulations, I provide direct evidence for colloidal diffusiophoresis and reveal how particle size, shape, and system dimensionality influence the resulting motion. Supported by NSF DMR-1944887

5:30-6:05 Yannick Pleimling - Zoom,

Title: *Ultrafast Carrier Dynamics in Core-Shell Nanoparticles*

Abstract: Plasmonic nanoparticles (NPs) offer large visible-light absorption cross sections [1] but are often chemically inert, limiting their application for photocatalysis. In contrast, transition metals (TMs) which serve as functional catalysts may not have large absorption in the visible range. By combining a plasmonic core with a TM shell, it may be possible to effectively harvest light to drive reactions for molecules adsorbed on the shell surface, for example, through photothermal heating or directly via hot carriers [2]. During my talk, I will discuss our preliminary efforts on characterizing the carrier dynamics in core-shell NPs consisting of Au cores and Ni shells of varying thickness. These dynamics are investigated via transient absorption spectroscopy, wherein the transmission of a broadband probe pulse through a solution of the NPs is tracked as a function of the time delay after the arrival of a pump pulse. The trends will be discussed and compared to recent literature on Au/Pd NP systems [2].

[1] Hartland, Chem. Rev. 111, 3858–3887 (2011).
[2] Stete et al., Nat Commun 16, 8168 (2025).